Facing together new challenges : the worldwide on going R&D work for the future nuclear energy systems

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Mr Chairman,
Ladies and Gentlemen,

We are honored to host and welcome this third workshop on the occasion of the fiftieth anniversary of the "Atoms for Peace" initiative launched by President Eisenhower on December 8th, 1953.

After several decades of industrial applications and in view of quite large prospects for the future of nuclear energy, trying to satisfy the world needs, it's indeed the right time to have a look on our current experience and to question ourselves about future solutions.

First, let's look towards the past; the question which raised after the second world war was: How nuclear energy can benefit the human beings and yet be banned for military applications.

The 1953 "Atoms for Peace" initiative laid out the major principles to solve this dilemma, a combination of carrot and sticks:

- cooperation for peaceful uses of nuclear energy will be promoted, satisfying a legitimate goal of progress for human kind;
- an international agency will conduct any kind of verification necessary to be sure that no one is diverting knowledge or materials for the wrong usage.

Today, the stability is still relying on the NPT, the Treaty on Non Proliferation of nuclear weapons concluded at the end of the sixties. At that time, most experts were fearing a quick and strong increase of the number of states trying to proliferate. Such figures as forty were often stated; fortunately, the success of international control has been wider.

At the end of the twentieth century, nuclear energy is used in a peaceful manner throughout the world by 40 countries and produces approximately 17% of the electricity. As a matter of fact, most of the production is in countries which are allowed by the NPT to possess nuclear weapons or which are industrially advanced countries.

The international control system has proved to be effective in a global view; there are still a few countries which have not yet signed the NPT, mainly three which are known for possessing nuclear weapons, and there are a few other states which should clarify their intentions.

Following the first Iraqi crisis, the International Atomic Energy Agency has drawn an additional protocol in order to enhance the commitment of states and to reinforce the legal authority of the Agency to implement further safeguard strengthening measures. It has still to be put in force in many countries.

But, let's first have a look at the situation in France.

EDF is currently operating a nuclear fleet of 58 PWRs producing about four hundred tera-Watt hours annually.

You all know that in France we are not considering nuclear spent fuel as a waste because it still contains a huge amount of energy valuable products but also because we will not be able to manage acceptable disposal of such a waste. Since 1990 and the fights we experienced in this country about projects of high level waste depository, we know better than to propose to bury spent fuels containing still 95% of valuable elements and a huge amount of long lived radioactive products.

The reprocessing option allows us to limit the ultimate waste to fission products and some minor actinides which we will try to burn also in the future. Most of the uranium recovered from spent fuels is stored, as a potential resource for the future and the plutonium is recycled in PWRs.

Twenty 900 Mwe PWRs are allowed to have one third of the core loaded with MOX fuel. They currently burn every year 100 tonnes of such MOX fuel, which is fabricated at the MELOX plant of COGEMA.

The present capacity of recycling plutonium in MOX loaded reactors limits the amount of spent fuel which can be reprocessed, the basic principle being to avoid to keep more plutonium on shelves that the amount which is needed for a flexible operation of the cycle.

Among the 1,100 tonnes of spent fuel which are discharged from EDF reactors every year, including 100 tonnes of irradiated MOX fuel, 850 tonnes of uranium oxide (UOx) fuels are reprocessed at La Hague Reprocessing Plant.

The final high-level, long-lived wastes including fission products and minor actinides are vitrified.

Let me stress once more that this strategy is based on the principle of equality of plutonium flows.

As far as economy is concerned, we can rely now on a real industrial feedback. The back end of the fuel cycle, as it is currently managed in this country, represents a small share, around 5%, of the effective cost of the kilowatt-hour. Many experts tried to compare this cost to the open cycle option. They concluded to a slight over cost, one or two percent of the kilowatt-hour cost. As nobody has ever experienced the direct disposal of spent fuels, it remains theoretical exercises without real impact on decisions.

In fact, we have to consider all the benefits of the reprocessing route: safe and long-lasting confinement of wastes in glass matrices, drastic reduction of the long term radio toxicity of wastes, preservation of up to 25% of natural uranium resources, reuse of valuable energetic material for up to 15% of electricity production.

The PWR Mox fuels have still margins of progress.

For example, MOX fuel is currently licensed in France for three in-core cycles only; that means a 3-batch reload scheme, which is the same schedule originally used for uranium oxide fuel. To take advantage of the rise in the authorized uranium fuel average burn up from 33 to 48 gigawatt-days per tonne (GWd/t), EDF adopted an hybrid reload strategy, a scheme that uses a 4-batch reload for uranium fuel, and just a 3-batch reload for MOX fuel. This strategy is obviously not yet optimal.

To improve it, it has been developed the so-called MOX parity project. This aims at achieving burn up parity between MOX and uranium fuels, and thus at implementing in 2004 a 4-batch reload management for both MOX and uranium fuels.

Reaching this burn up of 48 GWd/t on average will require raising the plutonium content of MOX to about 8.6 percent, a level at which stabilization of the separated plutonium inventory is achieved.

That is, the amount of plutonium contained in the 100 tonnes of MOX fuel loaded in the 20 MOX reactors is equal to the amount of plutonium extracted from the 850 tonnes of reprocessed fuel that same year.

Thus, the separated plutonium inventory will be limited at the level needed to dynamically manage the recycling process.

A few more reactors can be used to burn MOX fuels and further increases of the maximum burn-up will give the possibility to reprocess those UO2 spent fuels which are provisionally stored in La Hague pools.

Decisions concerning the reprocessing of MOX spent fuels are to be taken in the next few years taking into account the high level waste policy which will be precised in 2006 and the prospects of implementation of Generation IV systems.

Lets now consider the proliferation resistance concerns regarding the today's French option :

You all know that we are not underestimating the risk of proliferation and we are fully supporting the various measures which are taken on an international basis to try to avoid this risk. We have very strict domestic and international controls and we are fully convinced that they are suitable to avoid any significant diversion.

From the intrinsic/technical viewpoint, I would like to stress the following points :

- the plutonium coming from light water reactors, is not at all well suitable for nuclear weapons.

- we agree we cannot completely exclude a wrong use of it, even if it will be much more difficult than other proliferation routes.

- a reasonable way to limit the risk, while taking benefit of reprocessing, is to burn the plutonium as soon as possible after extracting it from spent fuels. It is what we are doing in France and what I have described above.

- last, we consider that from the non proliferation point of view it is better to burn plutonium rather than to keep it in store, even if it will be quite difficult to recover it from stored spent fuel with existing technologies.

Regarding the mid term evolution, it's a matter of fact that light water reactors will continue to play an important role during the 21^{st} century.

Of course, resources and waste management considerations are put at the highest level of criteria for future nuclear systems. But most certainly, none of them will be ready to operate, at a large scale, before 2030 or even 2040.

So it could be a wise policy to investigate the possibility of plutonium multi-recycling using Gen III LWRs.

The idea is to stabilize the plutonium inventory and it is a strong objective from both the natural resources and waste management perspectives, as well as for non proliferation reasons.

This goal cannot be achieved only by the present MOX mono-recycling option in a nuclear reactor fleet made up of current LWRs.

It is the reason why CEA is devoting R&D efforts on solutions that concern only the fuel and its cycle, but that require a validation program spread over several years.

This goal could be achieved with new, advanced fuel assemblies. Practically, we are looking for two solutions. One is derived from current plutonium fuel technologies. It consists in new plutonium assemblies, with islands of standard uranium dioxide (UO2) rods surrounded by MOX rods. A second solution requires further research and development. It consists of advanced assemblies, with a heterogeneous bundle including UO2 rods and annular rods made of plutonium oxide within an inert matrix.

Still another option would be to implement full MOX cores ; this is a possibility with Gen III reactors such as EPR and it is also an option we are currently studying with our Japanese colleagues for BWRs.

Considering the Generation IV Nuclear Energy Systems, an international consensus was found very quickly on criteria which are quite clear : Economics, Safety, Reliability will have, again, to be improved. But for these systems, proliferation resistance as well as sustainable development features are now top priorities.

For Sustainability it means an effective use of natural resources and minimization and management of nuclear waste.

For Proliferation resistance, it means systems as unattractive as possible.

With Generation IV , we are at the very beginning of the process. And, as far as non-proliferation is concerned, this is certainly a unique opportunity :

1.to adopt a new comprehensive nonproliferation strategy,
2.to implement measures from early design to operation stages,
3.to take benefit from the experience with safety methodology,
4.to take advantage from new technologies,
5.to achieve a global optimisation of the future systems,
6.to share the approach internationally.

Among the six concepts selected in the GEN IV exercise, most of them are fast neutron and closed cycle systems.

This is directly linked to the fact that :

1. they are top ranked in sustainability because of their optimum use of natural resources and their ability to reduce the radiotoxicity and the amount of wastes. Just on the volume criteria, the closed cycle would avoid the commissioning of 2 or 3 Yucca Mountain type repositories every century in the US.
2. there are rated good in proliferation resistance but also in safety, economics and physical protection.

Different coolants are considered for these systems. This is consistent with the fact that, considering the importance of this 'family', several routes shall be investigated in parallel.
Their first mission will be to produce electricity but they are also very well adapted for the management of actinides.

One could schematise, oversimplify a kind of 'perfect process' or 'ultimate one' for GEN IV fast reactor and closed cycle systems.

We are thinking of a reactor with an homogeneous fast core. Homogeneous core means in particular that there are no UO2 blankets that could produce fissile Pu, hence allowing its separate reprocessing. On the contrary, during the reprocessing & refabrication stage, all the actinides, Uranium, Plutonium and MA are processed all together at all the stages.

Considering that the core is, of course initially charged with fissile material, the system then is only fuelled with natural uranium and the only waste are ultimate Fission Products.

At this stage, I would also like to stress that this global actinide recycling option should be even more economical than the current reprocessing implemented in France ; the specifications on global actinide recovery and flux purification performances will not need to be as high as encountered today for separated actinide fluxes ; the system is also more integrated with minimal transportation costs.

It is obvious that such a system has great advantages regarding sustainable development, optimal use of natural Uranium and minimization of waste.

If this scheme is an ideal one, such systems are certainly interesting regarding non proliferation such as high burn up fuels, recycling process without separated plutonium, and extracting only fission products.

Such integrated systems, with compact technologies, with a minimization of transports will probably facilitate the implementation of detection techniques and controls, will strengthen physical protection and restrict the accessibility to the nuclear materials.

Of course, possibilities of safeguarding the systems will be looked at very carefully.

In order to launch the debate which will continue during this third workshop of Atoms for Peace, I would like to ask two questions :

- the GEN IV initiative that was initially launched by the United States, aims at widely developing long-lasting nuclear energy, for the good of humankind, so as to increasingly contribute to the production of worldwide energy, whether in the form of electricity, heat or a new energetic vector such as hydrogen. We should contemplate the possibility of multiplying the number of reactors by 4 or 5 during the first half of this century. How can we conciliate this voluntary goal with the confidence put in the stability of some countries?
- what position must the States take in terms of this development strategy for nuclear systems in the 21st century ?

The six concepts selected for the GEN IV systems nearly all have a closed fuel cycle, which, as we have already seen, is necessary for sustainable development. It is true that any type of cycle presents a risk of proliferation, even if other increasingly accessible and simple means, such as enrichment technologies, have been favored up until now.

Confronted with this potential risk, I believe that we do not have the authority, neither that we would be wise, to impose two different and distinct nuclear development modes depending on the degree of confidence put in the countries. In my opinion, it would be more reasonable, on the one hand, to work on reinforcing the robustness of the back-end of the fuel cycle, which is the role of R&D today, and, on the other hand, to work on obtaining an international consensus based on the principle of verification and inspection, with the two following essential aspects:

1. the analysis and verification of the “advisability” of facilities: that is verifying whether or not a country really requires these fuel cycle facilities in view of the physiognomy of its installed and planned nuclear capacities (i.e. type and number of reactors).
   Please note that the “systems” approach in GEN IV, which, at an early stage, takes into consideration the combination reactor and its associated cycle, is perfectly adapted to this “advisability” verification.

2. the inspection of these facilities within the framework of comprehensive safeguards agreements with additional protocols: What is produced in these installations? Are they used correctly, in compliance with the country’s peaceful commitments ?

Then we can imagine that countries will act according to their needs and possibilities and choose one or the other option :

1. those that will wish and choose to have the full capacities of combined reactors-cycle installations on their soil,

2. those that will opt for having only reactors, and for hiring out fuel cycle services.

In conclusion, let me summarize my personal views on what should be the bases of future development:

1. future reactors should be intrinsically more resistant to proliferation.

2. the closed fuel cycle, which is used today in France should evolve in the upcoming decades. It is highly favorable to sustainable development that will be beneficial to everyone but it will also strengthen resistance to proliferation.

3. the States should be free to choose their development strategy for reactors-cycle systems.

4. an international consensus must be reached based on an improved system of safeguards, which must be the key issue in the fight against proliferation.